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ETHICAL ISSUES IN TOPICAL COMPUTER VISION APPLICATIONS

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ABSTRACT

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Computer vision is a research area that contains multiple methods to approach numerous visual problems. In the past decade, it has been rapidly evolving with the introduction of many new technologies and applications that utilize different computer vision techniques. The purpose of this study is to identify the ethical issues that concern recent trending computer vision applications and their tasks. This was done by conducting an integrative literature review and synthesizing various studies that have been conducted on the different applications of computer vision and their ethical issues. The result was a synthesized framework of different ethics themes that relate to the different areas of computer vision. The results were presented in a written and visual representation of the current knowledge on the topic. It was made sure that the study is valid and reliable. Six categories of different ethical issues were recognized, which are espionage, identity theft, malicious attacks, copyright infringement, discrimination and misinformation. Based on the findings, a discussion was conducted to point out the several gaps that exists in the current research area of computer vision and its ethical issues. Further research on the topic was encouraged.

Keywords: computer vision, ethics, computer ethics

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1 INTRODUCTION

Computer vision is the field of research that deals with how computers can be made to understand different digital images and videos and the contents of these. The method for acquiring this information is conducted through analyzing, processing and understanding images or video presented to the software. In short, computer vision exists to automate the task of the human vision system. The technology itself consists of many different applications, like recognition, classification or detection. For the applications of computer vision, several branches of tasks exist, like content-based image retrieval, where software finds a specific set of images from the larger set based on search criteria or similarity or face recognition, where facial features are detected from the images or video. Since computer vision is a rapidly changing research area, the new innovations utilizing it are emerging fast. With any new and topical information technology, arises questions about the ethical practices of it. According to Quinn (2004), there is a need to approach every new technology in a thoughtful manner by thoroughly examining the technology and considering various issues the technology poses on the ethics.

The main motivation of this study is the lack of concrete and cohesive literature that sums ethical issues of the new topical computer vision technologies in one framework. The research area is therefore very topical and offers a good motivation to fill the research gap. This research gap exists, despite the fact that the software applications utilizing computer vision tasks are becoming available for public use in different forms of devices and platforms, like mobile phones and on the Internet, inevitably posing questions about their ethical implications.

The research problem and the research question of this study can be presented as follows: What are the ethical issues that concern recent topical computer vision technologies?

The research method of this thesis is an integrative literature review. The aim of the integrative literature review is an in-depth systematical review of existing literature, knowledge and theories, and the search for potential areas where new knowledge and observations are needed. This form of research

method serves well for a study that aims to review and synthesize related literature of the topic in such way that new perspectives are generated.

The main goal of this study is to define ethical issues of topical computer vision applications and tasks. The ethical themes were searched in the literature concerning computer vision, dating from 2000s forward. The ethical themes that emerged in the relevant literature were combined and synthesized to form a framework for understanding ethical issues of computer vision applications.

The first chapter serves as an introduction and describes a frame for this study, such as goals, research question and methodology. The second chapter provides an overview on what computer vision is, its distinction between machine vision, how the visual process of a computer vision works and a description of different computer vision applications. The third chapter provides an overview of how computer vision has recently progressed and what are the topical areas of its research area. The fourth chapter serves as an introduction to the ethics, describing what the different fields of ethics are and defining computer and professional ethics. The fifth chapter describes the method of integrative literature review and how it is conducted in this study. The sixth chapter provides results based on the integrative literature review, and synthesis is made from literature to form a visual framework and written explanation to ethical themes found from the sampled literature. Discussion on the findings is also provided in this chapter, along with analysis of the findings and evaluation of data of this study. The seventh chapter provides conclusion to summarize the results and offers discussion on possible future research.

2 COMPUTER VISION

This chapter provides a general description to the field of a computer vision by explaining the process of a visual system, its issues and applications. It serves as a chapter to introduce emerging computer vision applications: where they are categorized in the field of computer vision and how they are described to relate with the classification of a visual processing. The visual processing system is first described in three levels according to Marr's (1982) philosophy and the problem definition and constraints of computer vision are explained. After that, a description of applications of computer vision are provided and explained within different levels and categorized into different level categories according to the literature. The categories are the explained with examples of different computer vision applications. The issues of computer vision are then presented and the comparison between the function of visual processing of computer and that of a person is defined.

2.1 Introduction to computer vision

The first signs of computer vision as a discipline started formulating in 1960s. Since then, many notable publications on the description and issues of visual systems have emerged, including the wide amount of research on applications related to the field of study. However, despite a long history, computer vision remains to be a discipline that has a lot of challenging problems, and it's still an ongoing research area. Improvements and new applications are constantly emerging with the rapid advancement of technology, which require a lot of considerations and study of the discipline. (Szeliski, 2010, 22.)

The term of computer vision is not to be confused with other similar terms, such as machine vision or robot vision. By the definition of Ballard and Brown (1982), computer vision is seen to be more related to image and video processing and analysis and automating vision tasks by algorithms. On the other hand, according to Steger, Ulrich & Wiedemann (2016), machine and robotics

vision is a term that describes automatized inspection and analysis made by robots and various others hardware implementations used in different industries. Thus by the definition, machine vision utilizes the application of computer vision into manufacturing and industry and is of no interest to the scope of this study.

2.2 Description of visual processing system

To design successful vision algorithms for computer vision, analysis and specification of a problem and constraints from image formation and prior knowledge need to be fused with robust and efficient algorithms. In other words, vision algorithms consist of a fusion of statistical and scientific approach which is combined with the engineering approach. (Szeliski, 2010, 13.)

Marr (1982) has introduced three levels of description of a visual system that capsules the information processing. These levels are:

- *Computational theory level,* which describes the goal of the vision task and constraints that are recognized or that arise with the identification of a problem.
- *Algorithms and representation level,* which describes what kind of algorithms are used to calculate desired results and how input and output information is represented.
- *Hardware implementation level*, which describes how algorithms and representations are mapped into the hardware, such as graphic chips (GPU) or central processing units (CPU).

While forming a task for a visual system, it's important to decide on the specification and constraints of a problem to come up with well-defined problem definition. The purpose of this is to constrain the problems that are potentially open-ended, to come up with a suitable technique for a desired task. (Szeliski, 2010, 9.) Much of the computer vision requires estimating unknown qualities and solutions to inverse problems. That is why the technology relies heavily on algorithms that are known to work in practice. The algorithms must both match realistic world conditions and lend themselves a consistent and stable estimation of the unknown factors. Capable computer vision requires both to be robust and reasonably efficient in terms of space and resources of runtime. (Szeliski, 2010, 10.)

2.3 Applications of computer vision

As the intended objective of computer vision is to be as close as possible to human visual perception, the robustness of a computer vision algorithm is com-

pared to observing human performing a similar visual task. Robustness, in this context, is the ability to extract the relevant visual information for a certain task, even when the available information is contained within a small portion of data and is different from the already stored data and visual representation. (Medioni & Kang, 2004, 109.)

The usability of computer vision techniques is important, since computer vision is applied science (Olague, 2016). Various ranges of mathematical and computational methods are utilized to solve vision perception related problems. The main subjects where computer vision is applied are divided into different categories. The categories can be divided into low, mid-, and high level categories and according to Olague (2016), the categories are as follows:

- *Low level category,* which includes Feature extraction and Matching and registration.
- *Mid-level category,* which includes Image segmentation/clustering, Image classification and Motion analysis (video).
- *High level category,* which includes Sensor planning/calibration, Object Recognition, Visual learning and Face recognition and modeling.

The low level category can be seen as the early stages of visual processing. The category is often described to deal with extraction of certain real-world properties from the images, such as object boundaries, surface or texures. The quality of an output from the low level category is important, since it serves as a crucial part of the whole process in the computer vision chain. The extraction of features is used to solve many of the various image-related problems. Matching and registration is an important procedure to transform various data into coordinate system to determine positions of point of interests on a manifold. (Olague, 2016, 44.)

The mid-level category provides a connection between low and high level category stages. The aim of this category is to provide perceptual representations in a form of symbolic representation translated from the images. With the acquired representations, a high-level process can operate to achieve perception understanding. In this category, different segmentation, clustering and classification techniques are implemented to achieve that: segmentation is used to divide the whole into groups, clustering is used to organize object into groups, and classification is used to identify and classify pixels of the image into classes or themes. Motion analysis gets information about objects that are in motion, which is taken from video image. (Olague, 2016, 44.)

The high level category deals with cognitive deductions made by the computer vision system. This category includes several tasks, which include image identification, recognition and analysis. Its main application is content based image retrieval (Yang, 2004). Sensor controlling is concerned with what to predict to sense from the image, object recognition is used to identify an object within the image, visual learning concerns the task of putting relevant information and data to images, and face recognition and modeling is used to au-

tomatically identify and verify persons from the image. All of the mentioned categories serve the task of recognizing information from a picture (Figure 1), and complement each other in various computer vision tasks. (Olague, 2016, 45.)

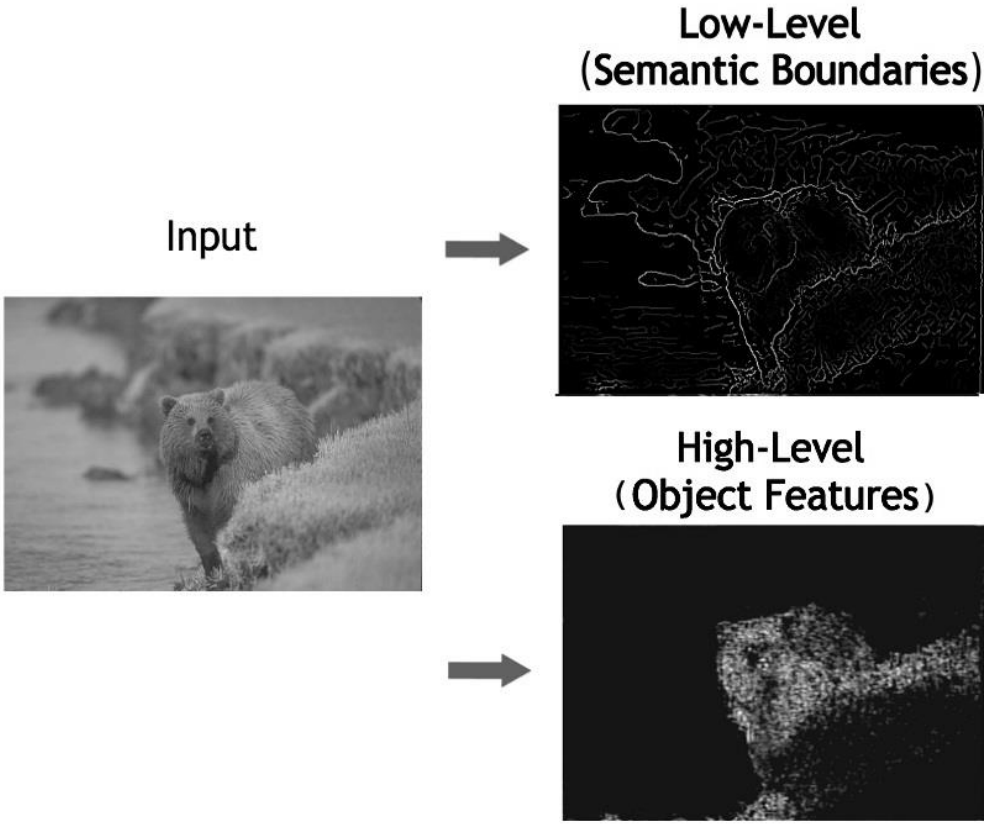

FIGURE 1 Low- and High-level category (Bertasius, Shi & Torresani, 2015)

2.4 Issues in computer vision

The hierarchy mentioned in the chapter above is difficult to categorize for the visual perception of a living person, because human vision appears to be a single integrated unit. The visual tasks performed by human are a vast flow of top-down information which carries the representation derived from higher levels, which control visual processing at lower levels **(**Medioni & Kang, 2004, 110**).**
The interpretation with our visual system is carried out with ease. We see the scene before us as it is, for example trees in a landscape. No noticeable deductions are required to interpret and understand each scene, and the interpretation of the scene and objects comes almost immediately.

For a computer, the image consists of numerous numbers stored by it, usually in the electronic medium. The process of retrieving relevant information from an image is carried out by the computer in a highly different manner compared to the human eye, even with recent advancement in computer vision technologies (Figure 2).

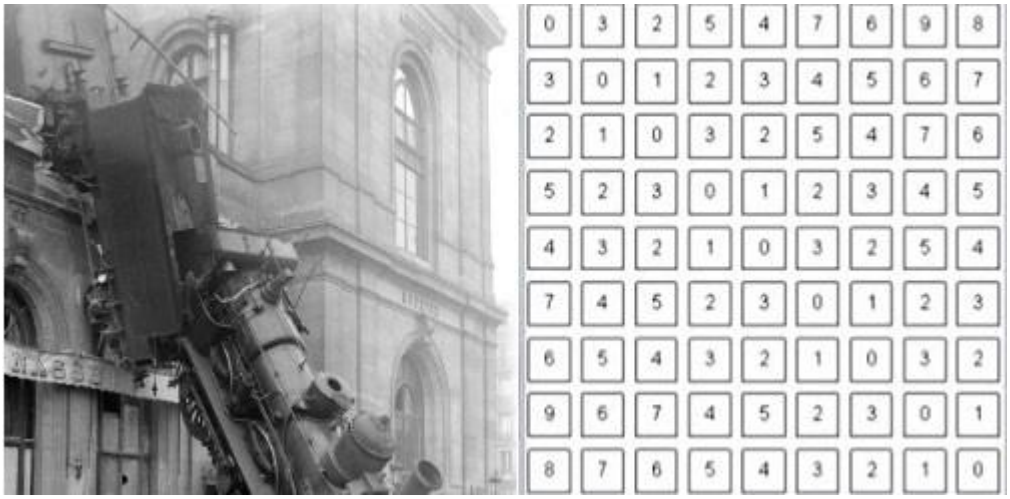

FIGURE 2 What computer sees in an image (Forsyth & Ponce, 2003)

It remains a fact that we are still unaware for the most part of the complexities of a human vision. To interpret things with the visual system is not a simple process, and the human visual system has evolved over millions of years. (Davies, 2012, 1.) The performance of computer vision algorithms is still far behind when compared to the human visual perception.

3 RECENT PROGRESS IN COMPUTER VISION APPLICATIONS

This chapter provides a detailed description of the current topical computer vision applications with examples. In this context, the term topical computer vision application *is* used to describe the trends of 2000s in the field of computer vision. Since recent applications utilizing computer vision are more advanced and complex in nature, they can be seen as most controversial regarding ethics and a central interest for the point of this study.

In the first subchapter, a short overview of recent computer vision trends is provided as introductory. The second subchapter examines computational photography and different applications utilizing it. The third subchapter examines the recognition techniques, with emphasis on face recognition, image search and databases. The fourth subchapter examines topics of cognitive Internet services and Internet computer vision.

3.1 Overview of recent computer vision trends

Szeliski (2010) lists various computer vision techniques that have recently become topical in the past decade in the field of computer vision research. The recent trends of the past decade in computer vision have been continuing to merge the fields of vision and graphics. Many new trends include techniques like image stitching, rendering and high dynamic range (HDR) capture. Since such computer vision techniques are used in everyday photography and filming, they are labeled under a single term computational photography. (Jahne, 2000, 610; Szeliski, 2010, 18.)

The second emerging trend of computer vision is feature-based techniques, which are combined with learning for recognition applications. Recognition based techniques dominate tasks such as face recognition, scene recognition, location recognition, or action and motion recognition. (Szeliski, 2010, 19.)

The third prominent trend, which is currently topical in visual research, is the use of computer vision techniques in the setting of the Internet. This trend has become more profound with the availability of immense quantities of data on the Internet. The large amount of available data makes it more feasible to learn categories of object from images without the assistance of a human. Search engines have also been made to utilize various computer vision techniques. (Szeliski, 2010, 19.)

3.2 Computational photography

Computational (smart) camera techniques are utilized in modern digital cameras. Additional computational techniques include texture synthesis, quilting and inpainting, and these techniques are used to produce new photographs by recombining input image samples. (Szeliski, 2010, 19).

There is wide range of different techniques that fall into the category of computational camera techniques. High Dynamic Range (HDR) imaging is a technique that combines multiple exposures of the camera to achieve the full range of brightness to the scene of the taken image. Image stitching includes techniques like cutting pieces of a photograph to fill another image. This technique can be used to efficiently patch the holes or missing sections in a taken picture. Rendering techniques are used to directly manipulate taken photographs. This can include making pictures look like drawings or paintings. Other techniques like texture synthesis, quilting and inpainting (figure 4) are used to modify or improve pictures. (Szeliski, 2010, 467.)

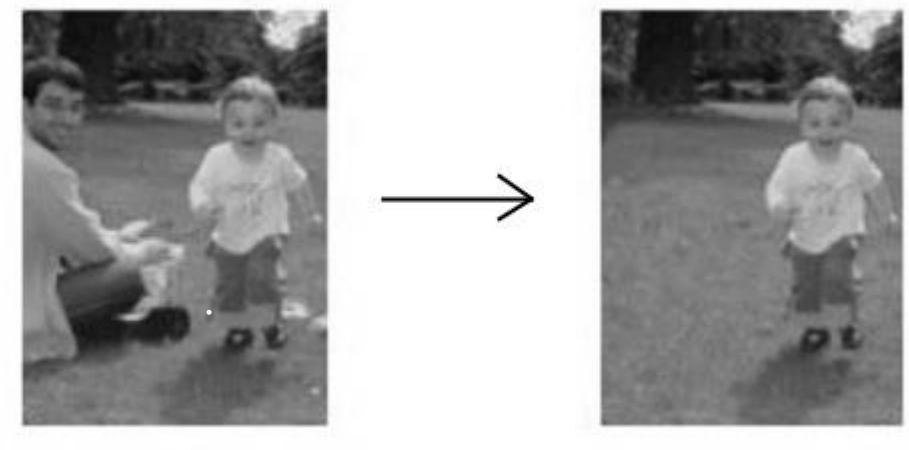

FIGURE 3 Inpainitng by smart camera (Criminisi, Perez, & Toyama, 2004)

3.3 Recognition

According to Davies (2012), recognition is essentially about discriminating between different patterns of different classes, but also generalizing the patterns of the same class. Analyzing the scene and recognizing objects from the image remains to be one of the most challenging problems in the field of computer vision. The challenge of recognition lies in the complexity of the real-life objects and high variability of different poses, angles and how objects occlude with each other. Since consistent recognition is so hard to achieve, it requires robust algorithms and a large database of exemplars. The most challenging version of recognition is general category or class recognition, which involves recognizing varied classes or object instances, like different breeds of dogs. (Szeliski, 2010, 657).

3.3.1 Face recognition

The most notable use of recognition is face recognition, which can recognize and classify facial features from the images. Face recognition techniques have proven to be the most successful application in the research area of computer vision, due to the fact that a lot of researchers seem to be especially interested in this application (Zhao et al., 2003). Face recognition is usually done by recognizing distinctive features such as eyes, nose and mouth, and verifying if they are in the realistic geometrical arrangement, as seen in (Figure 3). (Szeliski, 2010, 657).

FIGURE 4 Face features detection (Hsu, Abdel-Mottaleb & Jain, 2002)

3.3.2 Other recent recognition techniques

In addition to a lot of research on face recognition, several other recognition techniques has also received a lot of attention in the field of computer vision. Some of these include techniques that focuses on the detection of objects like

pedestrians and cars. Various methods exist to identify such objects with focus on speed and efficiency of recognition, while other methods exist to focus on accuracy of detection. (Szeliski, 2010, 666.) Another notable recognition technique connected to object recognition is location recognition, which is used in desktop and mobile applications, and can determine the location of the image based on its contents and can provide navigational directions or other location-relevant information (Szeliski, 2010, 693). However, not all recognition techniques rely solely on just images. Action and motion recognition is used to analyse and derive different information from video feedback (Szeliski, 2010, 343).

One of the integral parts of recognition techniques is the use of large image collections. A good example of a large database used for recognition is ImageNet (Deng, Dong, Socher et al., 2009). (Figure 5) describes how labeling is done for the set of images in ImageNet database. Large databases of labeled images like this have enabled the rise of many Internet based sub-fields of computer vision in the past decade (Avidan, Baker & Shan, 2010).

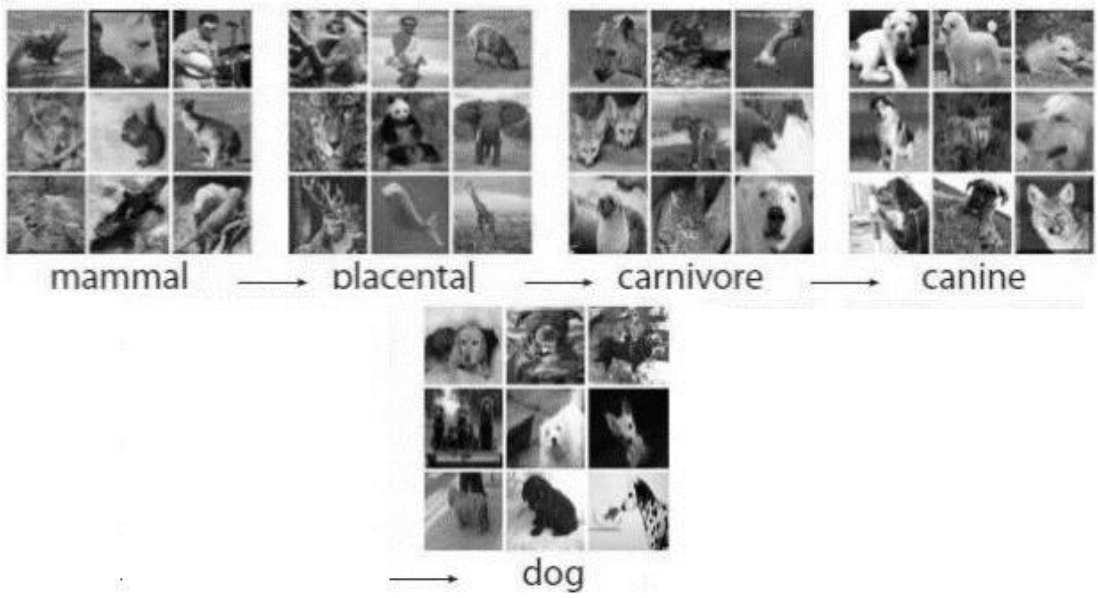

FIGURE 5 Image labels in ImageNet (Deng, Dong, Socher et al., 2009)

3.4 Computer vision on the Internet

The cognitive development of computer vision related technologies has bought increasingly more possibilities to the computer vision researchers, and it can be seen in increasing public availability of different services over Internet and on mobile. Especially in recent years there's been a substantial amount of different available cognitive services, like Microsoft's CaptionBot. (Tran et al., 2016). These cognitive services and APIs (application programming interfaces) are offered to private personnel or corporations for different fees.

The technologies utilized in such services are image recognition related to deep learning and different face, scene, character or text analysis. (He et al., 2016.) The main feature is to either provide information to the presented image by the user to receive information about the image in the form of text (Figure 6), or find an image from database based on the keywords or tags that the user chooses or types into the program.

FIGURE 6 CaptionBot analysis (Tran et al., 2016)

3.4.1 Image search and databases

Most search engines related with image search rely on information like file name and captions (Craswell & Szummer, 2007). According to Szeliski (2010), use of computer vision techniques such as visual features and visual similarity is becoming more common to recognize images that have missing or broken keywords. The retrieval of images from the Internet thus utilizes both keywords and visual similarity of images as combination.

The retrieval techniques go by the variety of different names, such as content based image retrieval (CBIR) (Smeulders, Worring, Santini et al., 2000) and query by image content (QBIC) (Flickner, Sawhney, Niblack et al., 1995). According to Szeliski (2010), the availability of image databases used by these retrieval techniques are continuously improving with more robust recognition algorithms and increasing quality and availability of different image databases.

3.4.2 Internet computer vision

According to Avidan, Baker and Shan (2010), the existence of large image database has given opportunity for a unique subfield, Internet Computer Vision, to rise. The main focus of this area is to extend available Internet related content, such as image search engines, image databases and collections and other set-

tings of the Internet to adapt to various computer vision technologies and algorithms.

Without a doubt, the existence of the Internet and the fact that it offers the largest and diverse library of photo collection has enabled computer vision researchers to exploit it in many applications (Snavely, Seitz & Szeliski, 2008). Additionally, the Internet can be used for more than a source of data. Computer vision field has been recently evolving to help users of the Internet to navigate through vast collections of visual information.

Computer techniques used in Internet consist of content based image retrieval, called reverse image search, where the user inputs manually a visual query to the search engine, which in turn returns to the user similar images, metadata and other information about the image (Figure 7). These computer vision techniques are available in different image search engines, such as Google, Bing or Yahoo image search. (Xu et al., 2010.)

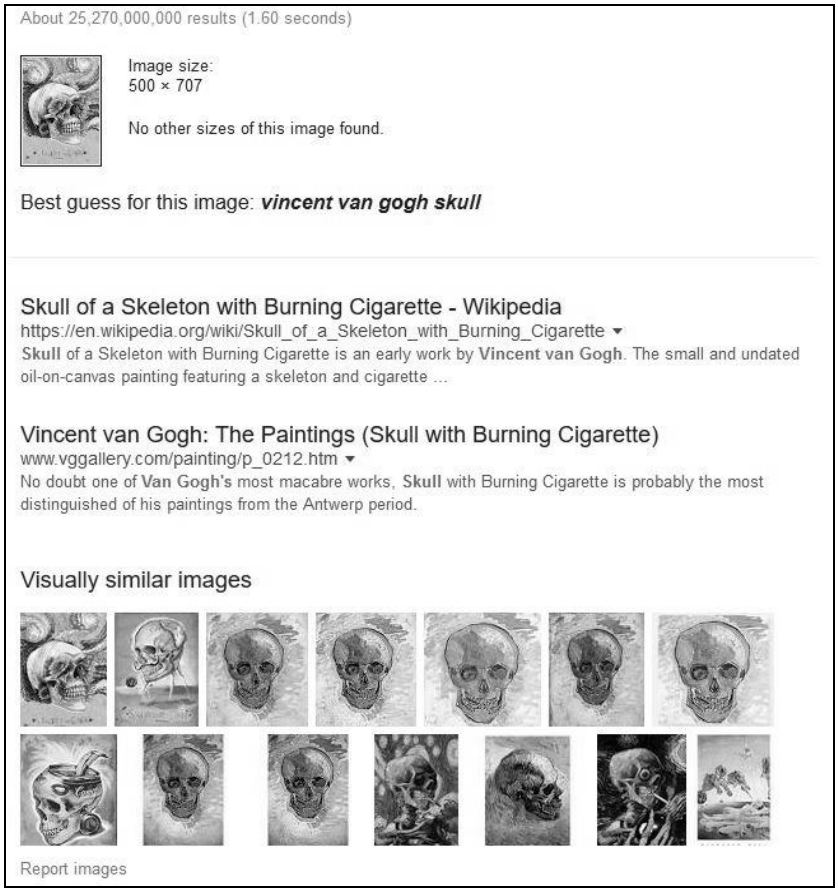

FIGURE 7 An example of Google's reverse image search

4 ETHICS

This chapter examines the study of ethics and different interpretations of it by various fields of study. The distinction between different terms and synonyms is brought up, while different themes of ethics that arise in different fields of study in ethics are also examined. This chapter also serves to introduce computer and professional ethics, which have important significance to this study.

In the first subchapter, a definition of ethics is given to differentiate between similar terms such as morality. The definition of the term ethics is also explored. In the next subchapter, the different fields of studies of ethics are examined and described. The third subchapter examines meta-ethics and how the field is divided. The fourth examines normative ethics. Lastly, a brief description of applied ethics is provided as an introduction to the next subchapter. The last subchapter examines the field of computer and professional ethics.

4.1 Definition of ethics

The term morality refers to the widely shared social conventions about what is right and what is wrong. Being widely shared, morals become the basis of established consensus. Different moral dilemmas might arise, people can have different opinions on morals based on their age, gender, ethnicity and religion, and people can belong to many societies simultaneously. (Reynold, 2011, 3.) In this context, a term *society* refers to a group of people who organize themselves under a system of rules, which serve by advancing the good of its members (Quinn, 2014, 52).

The philosophical study of morality is called ethics. The purpose of ethics is the rational examination of moral beliefs and behavior of people (Quinn, 2014, 53). While morals are beliefs of individuals on what is right and wrong, ethics exist to describe standards or codes of individual's behavior. Behavior is determined by a group in which the individual belongs to, like nation, organization or their profession. (Reynolds, 2011, 5.)

4.2 Different fields of studies in ethics

According to the Internet Encyclopedia of Philosophy (n.d.), the study of ethics can be divided into three different major areas, which are meta-ethics, normative ethics and applied ethics. It should be noted that the lines between each of the field of ethics is not concrete, and that the lines between each field of study are blurred. General consensus stands however that the field of meta-ethics investigates the source of ethical principles and their meaning. Normative ethics investigates ethical issues on a more practical level, examining moral standards. Applied ethics, on the other hand, examines specific issues concerning ethical conducts in public and private life.

4.2.1 Meta-ethics

The core of meta-ethics, according to Fisher (2014), is the purpose to understand the practice of ethics. Meta-ethics first gained identity as a field in Moore's (1903) book Principa Ethica, which also served as a beginning point for the ethical theory of twentieth century. Roughly, meta-ethics can be divided into three areas, in which each of the area is systematically analyzed (Fisher, 2014). The areas are as follows:

- Moral language
- Moral psychology
- Moral ontology

Moral language is considered to be as an examination of what kind of moral talk people discuss. Moral language essentially describes what people mean by describing something as "wrong or "good". *Moral psychology* refers to meta-ethical examination of how people make moral judgments and reasons and motivations for their behaviors. *Moral ontology,* on the other hand, examines if the perceived moral properties are real and existing, and whether morals are independent or causal. (Fisher, 2014.)

4.2.2 Normative ethics

Kagan (1992) describes normative ethics as a principle which purpose is to create practices, values and standards on the basis of moral actions. Within normative ethics, three theories exist, which follow certain strategies: virtue theories, duty theories (also deontological) and consequentialist theories.

Virtue theories are based on the teachings of Aristotle, and are a belief that morality should consist of habits that are in nature benevolent. The habits must be widely accepted and in essence considered as good. The end-goal of such habits is a good and purposeful life. (Hursthouse, 1991.)

Duty theories, according to Kant (1998), follow the idea that morality is based on the principle of obligations and duty. The reasoning behind moral choices is guided by the belief of obligation to something, like law, and the action itself is seen more important than its consequences.

Consequentialist theories follow the principle that the moral is determined by the consequences of actions (Railton, 1984). This means that the taken action is seen as morally right, if the consequences are favourable and outweigh unfavourability. If the good consequences are greater than the bad, the morality of the action is considered 'proper'.

4.2.3 Applied ethics

According to Moor (1985), the purpose of applied ethics is to analyse specific moral issues in different scenarios or fields. Unlike with theoretical ethics, applied ethics examines the practical side of ethical issues from the point of view of one or several ethical theories. Thus, applied ethics is the most relevant study of ethics to the field of information technology. The purpose of the applied ethics field is to apply ethics to the analysis of the moral problems themselves, rather than to debate the theories.

Different categories of applied ethics consist of ethical subfields that are relevant to IT, such as information ethics and computer ethics (Quinn, 2014). The further examination of both categories of applied ethics is conducted in the next subchapter.

4.3 Computer ethics

Moor (1985) defines computer ethics as a research area that deals with the analysis of the social impact that computer technology causes. Computer ethics is a branch of information ethics that has been built on the foundation of information ethics (Floridi, 1999). It can be seen as a more practical approach to ethics, based on the philosophy of information ethics.

The term computer ethics, or cyberethics, is also used to refer to a kind of ethics issues associated with the Internet. In addition, it's also used to describe professional ethics, where computer professionals apply good ethical standards within the profession (Bynum, 2016).

There seems to be a great consensus that information technology holds many ethical issues (Moor, 1985; Floridi 1999; Reynolds, 2011; Quinn, 2014). The implications of this can be seen in many things: The rapid growth of the Internet, the fast expansion of storage and vast amount of personal data, and increasing reliance on information systems. These factors have all increased the risk of unethical use of information technology. (Reynolds, 2011, 24.)

4.3.1 Common issues in computer ethics

Identifying ethical issues is not a straightforward action and is usually considered complicated due to the nature of ethics and how they are perceived by different people and different cultures (Quinn, 2014). For computer ethics, several professional societies have made documents describing behavioral guidelines in the form of code of ethics. Association for Computing Machinery (ACM) lists code of ethics for computing users and professionals. According to the code of ethics by ACM (1992), topics like privacy, security and intellectual property are included in the code of ethics and professional standards.

4.3.2 Professional ethics

According to Quinn (2014), professional ethics exist in the area of computer ethics. This is similar to other research areas having own ethical professional ethics, like photojournalism, medical or legal ethics for example. Different areas of professional ethics can thus have their own impact on computer vision technologies, aside from computer ethics.

Generally speaking, profession ethics includes different responsibilities that professionals have towards their customers, coworkers, employees and whom their products or services affects. Certain actions and decisions of professionals can create various ethical dilemmas and have different kind of consequences. No defined special aspect exist in the professional context when making ethical decisions, but they are generally based on general ethical theories and principles. (Quinn, 2014, 405.)

5 RESEARCH METHOD

The research method of this thesis is an integrative literature review. The aim of the integrative literature review is an in-depth review of existing literature, knowledge and theories, and findings of potential areas where new knowledge and observations are needed. This form of research method serves well for a research that aims to review and synthesize related literature of the topic in such way that new perspectives are generated. (Torraco, 2005.)

In this chapter, the basics of integrative literature review is first examined. Secondly, an overview of the previous publications is given. Next, the various stages of integrative literature review are introduced, starting from the collection of data and continuing to reviewing the databases and keywords used in the search, and lastly how the data is excluded and included, the screening process, how the yielded literature is analyzed and classified, the expected results, and finally the limitations of this study.

5.1 Integrative literature review

According to Torraco (2005), the integrative literature method is conducted as follows: First, a critical analysis on literature and deconstruction of elements into topics is done. Secondly, a synthesis of the literature is done to interpret multiple researches to identify common themes and to transform the studies into new interpretations and knowledge.

The integrative review process consists of five stages which are: problem formulation, data collection or literature search, evaluation of data, data analysis and interpretation and presentation of results. The integrative research method must be conducted thoughtfully and with great emphasis on details, and the outcome of the research needs to be a contribution to appropriate area of research. (Russel, 2005.)

5.2 Previous similar publications

An extensive database search for publications on ethics related to computer vision in effort to find if this kind of study has been done before did not return any results. There is no prior research conducted that encapsulates ethical issues of computer vision in the same way that is the purpose of this study. The combinations of keywords that were used were 'ethic', 'computer vision', 'machine vision', and 'moral' in different databases. Any found publications were either on different sub-categories of computer vision, such as face recognition, or different empirical studies on computer vision applications with considerations to ethics. This serves this study well, as the purpose of this study is to integrate publications like that into a combined framework. This also means that this study is bringing new knowledge to the topic and hasn't been done before.

5.3 Data collecting

Souza, Silva & Carvaho (2010) propose a step by step guide for the integrative literature review. The data for the research is collected by searching and sampling the literature from the databases. The search is done by using relevant keywords (for example ethics + face recognition) combined with manual search from published journals and books. Depending on the amount of found literature, the inclusion and exclusion criteria of publications is discussed. It is made transparent that the included publications represent the study properly by including the instrument for search in the appendix. In the cases where the amount of publications on certain topics is too large, random sampling is used to narrow down the results.

The collected data is examined for its reliability by face value. The collected data includes relevant information such as authors, concepts and the methodology used. The final sample literature is listed in the appendix. A proper instrument for data collection is used when sampling the literature, taking into account Creswell's (2013) note that the instrument should provide reliability and validity to the research.

5.4 Data sources and keywords

The first stage of the integrative literature review is to set a broad scope of using a sufficient amount of electronic databases, according to Torraco (2005). The following databases are used for the search: ACM, EBSCO, JSTOR, IEEE, Springer, Science Direct and various other scholarly databases. Additionally, Google Scholar is used to perform horizontal searches to find additional sources for articles that may not be available for access on the initial sites.

The search terms are defined in accordance to the research question and the theoretical background of the research. To prevent possible scarcity of search results and to attain a sufficient coverage of the literature, a broad set of terms is used. (Creswell, 2013.) The word "ethic" is used along with a term related to the computer vision context, for example "face recognition". Because the use of terms or the content of research articles may vary between authors of publications, different computer vision applications are used along with their synonyms based on the theoretical findings, such as "ethic AND face recognition" or "ethic AND face detection". The ethical themes themselves are not predefined in the theoretical part of this study, but are instead collected and sampled from the found literature in literature review. The list of search terms used for computer vision technologies are as follows:

- Computer vision
- Face recognition
- Object recognition
- Location recognition
- Content based recognition (CBR)
- Query by image content (QBIC)
- Content-based image retrieval (CBIR)
- Reverse image search
- Image database
- Image retrieval
- Image classification
- Smart camera
- Smart photography
- Intelligent camera
- Cognitive services

The known problem is that some authors may not use the word "ethic" when describing ethical problems in their literature. Thus, synonyms and similar terms related to ethics and computer ethics context are used, based on the theoretical background of the research. The terms are as follows:

- Ethic
- Moral
- Privacy
- Security
- Copyright
- Accessibility

Inclusion of these search terms might reveal more articles, which are relevant to the conducted literature search. However, as Russell (2005) claims, it is not expected that the reviewer obtains all possible studies for the literature review, and that it is not even realistically possible.

5.5 Inclusion and exclusion of data

According to Whittemore and Knafl (2005), the inclusion of grey literature, like theses, presentations and other literature outside academic publishing is not advised, as it is considered to be time-consuming and yields very little relevant data to the review itself and the researchers. However, published conference proceedings are included in the search, as they most likely contain possible relevant up-to-date data to the research due to the short lifespan of information technology field itself, and due to the scope of study. Only papers written in English are included in the research, dated 2000-2017 as according to the scope of the research.

The reviewed literature is excluded if the research design of studies seems poor or unclear or the arguments presented are not reasoned well or clearly. Additionally, empirical research is evaluated based on its measurement tools, analysis and relevance to the development of knowledge. Theoretical articles and conference proceedings are evaluated based on the ability of the writer to present ideas clearly, relevantly and in an unbiased way. (Creswell, 2013.) Theory is evaluated by logic and clear reasoning on basis of explanations and arguments presented (Whetten, 1989).

Literature is screened with a goal to include only information technology relevant scholarly articles. Since integrative literature review promotes inclusion of different kinds of types of methodologies according to Souza, Silva and Carvaho (2010), the inclusion consists of both theoretical and empirical research papers.

5.6 Screening process

According to Russell (2005), the screening process is crucial for data evaluation and the steps conducted for screening should be apparent to the reader. The screening of articles is essentially done in three steps in this study. In the first step, after a broad search, titles and abstracts of articles are collected and possible duplicates are eliminated. In the second step, the collected titles and abstracts of articles are screened using the inclusion and exclusion criteria. During this step, the relevant articles are manually selected for the next step. In the last step, remaining articles are then fully read in a careful and precise manner to further examine them in the light of inclusion and exclusion criteria. The result is a collection of carefully screened articles based on the inclusion and exclusion criteria, all of which meet relevance to the topic.

Additionally, the reference lists of selected articles is used to identify more relevant articles of interest to the topic. Some of the article search is thus conducted manually.

5.7 Data analysis and classification

The themes of ethical issues that arise from different publications concerning computer vision are analysed and compiled into a framework. Possible gaps in the knowledge are discussed. Results are formulated based on the theoretical reference and the proposal is suggested for the future research.

Since the research method is integrative, a synthesis of different categories and research types can be made to form new knowledge (Souza, Silva & Carvaho, 2010). For example, some ethical issues of big data could be identified to have same issues that large databases of image recognition software have, as long as integration is viable.

To accomplish a successful integration and synthesis, an effective breakdown of a theory is needed (Souza, Silva & Carvaho, 2010). This means that the research area of computer vision must be studied thoroughly to identify different sub-categories of the research area. The identified sub-categories are then used as keywords for the search of relevant publications on the topics.

The final group of screened articles are divided to a comprehensive form by their publication type in the form of writing. According to Whittemore and Knafl (2005), proper data analysis requires that the data from sources is ordered and categorized. After that, the data is summarized into integrated conclusion from which the results and findings can be derived.

According to Souza, Silva & Carvaho (2010), the presentation of data and results must be done so that the findings are converted into a visual form. The visualization can be depicted in forms of tables, graphs or charts. The visualization must also contain the identification of patterns, differences and distribution of topics based on the found themes.

For this study, empirical and theoretical articles are summarized in writing and then synthesised by the themes of computer vision applications. The articles are then coded and summarized in a form of table, in which the computer vision application, its ethical issues, and the studies where data was found from are presented (Table 1). This type of table serves well for the synthesis of the literature, as it shows all information relevant to the topic and indicates the source of information in an easy to read format for the reader.

TABLE 1 An example of a synthesis of literature

Computer vision Technology	**Ethical issue(s)**	**Studies**
Face recognition	x	[1], [2]
Image retrieval	x	[3]

The reviewed literature is also listed in the appendix in the form of instrument used to collect the data. It shows various information about the research papers used to collect results, as well as the database they were found in, the journal/book/conference proceedings they originally appeared in as well as the keywords that were used to search them.

5.8 Expected findings

The themes of ethical issues that appear from different publications concerning computer vision are analysed. Each ethical issues arisen form the literature is analysed separately in written form with its connections to various computer vision technologies. Computer vision areas that have a lot of ethical research are noted, and areas that lack research or do not have any research are pointed out. Possible gaps in the knowledge are discussed and different proposals are suggested for the future studies concerning ethical research of the computer vision. The results and finding are presented in a way which is recommended by the various papers providing guidelines on how to write a reliable integrative literature review. This is done so that the results are meaningful and make contribution to the research area.

5.9 Limitations

There are some notable limitations to this study. First of all, it is impossible to include all relevant keywords in the search keywords, as that would expand the results to the amount so large that it would be really time consuming to examine all research papers with the available resources. For example, security as a keyword combined with computer vision potentially results thousands of articles that do not examine the security issues, but rather just have the word security somewhere in the text. That is why some of the keywords were set up so that the search engine searches them in the abstract and keywords section, rather than in the full text of research papers.

Another limitation is the use of terminology in the field of computer vision and ethics. Because of the fact that some terminology is not set in stone, different researchers might use different names and meanings for computer vision and ethics related technologies and issues. For example, a computer vision technology commonly known as content-based retrieval has many different names and styles to write it, such as CBIR, query by image content (QBIR), content-based visual information retrieval, concept-based image indexing, or simply content based image approaches. Including all of the variations of terms used as keywords in search is not realistic from the perspective of resources given to this study as it would be too time consuming, but great emphasis was given to include the search words that were most commonly used in the theo-

retical base of this study to maximize the reliability of the findings. Additionally, in some cases, certain abbreviations of computer vision applications might have different meanings and not relate to computer vision. That is taken account in the exclusion criteria.

6 Results

In this chapter, each ethical theme found in literature is examined and the synthesis and critical evaluation of finding is discussed. The purpose of this chapter is to integrate the final sampling of papers and to obtain knowledge related to the computer vision and the current state-of-art regarding the ethical concerns the field contains.

The purpose of the first sub-chapter is to visualize the results in a single form of visual framework and review the basic information of the conducted search. In the next subchapter, each ethical theme found in the integrative literature review is examined in the light of findings. In the last subchapter, findings are critically evaluated, knowledge based on findings is formulated, and possible gaps and discrepancies in findings are evaluated.

6.1 Synthesis of literature

In this subchapter, findings are compiled and presented for the purpose of assisting further examination. The initial search with keywords yielded overall 34 results. The sample after the final screening was reduced to overall 18 papers, of which 9 were empirical and 9 theoretical. The final sample was included in the visual framework and listed in the appendix. The ethical themes found in the sampled literature will be examined in the next subchapter.

The purpose of integrating results in a single visual form like a table is to determine different patterns and directions as to which areas sampled studies concentrated the most or the least. It also helps to provide additional information of interest to the readers, as different computer vision applications can be easily compared with each other in this format. It also serves as a good outline for the further examination of the topic in the next chapters.

Compiling the information for an easy examination and critical assessment in its entirety is part of the process of integrative literature review. Findings from the final sample of research papers were compiled into manageable

and comprehensive visual form as seen in the following table, in order of most ethical issues to least (Table 2).

TABLE 2 Synthesis of literature

Computer vision Application	**Ethical issue(s)**	**Supporting studies**
Face Recognition	Identity Theft	(Tian et al., 2011)
	Discrimination	(Tian et al., 2011)
	Espionage	(Tian et al., 2011), (Grand-jean et al., 2008)
	Malicious Attacks	(Jain & Kumar, 2012)
Computational camera	Espionage	(Senior & Pankati, 2011)
	Misinformation	(Quinn, 2003)
	Malicious attacks	(Winkler & Rinner, 2010), (Winkler & Rinner 2014)
Image Database	Copyright Infringement	(Gloe & Böhme, 2010)
	Espionage	(Puglisi et al., 2015), (Senior & Pankati, 2011)
Action and Motion Recognition	Espionage	(Padilla-López, Chaaraoui & Flórez-Revuelta, 2015)
	Discrimination	(Coudert, 2010).
Character Recognition	Identity theft	(Dey et al., 2014)
	Espionage	(Senior & Pankati, 2011)
Content-Based Image Retrieval	Identity theft	(Zhuo et al., 2013)
	Copyright infringement	(Müller et al., 2004)
Image classification	Identity Theft	(Lorenzi & Vaidya, 2011)
	Espionage	(Spyromitros-Xioufis et al. 2016)
Reverse Image Search	Malicious Attacks	(Lorenzi et al., 2015), (Mehrnezhad et al., 2015.)

6.2 Assessment of ethical issues

The purpose of this subchapter is to derive the ethical themes from the visual framework of the previous chapter. Each ethical theme will be presented with the computer vision applications that relate to it. Ethical themes will be assessed in writing, which will include references to the literature they were found from. Overall, 6 different categories of ethical issues were recognized from the sampled literature: Espionage, identity theft, malicious attacks, copyright infringement, misinformation and discrimination. The order in which the themes are presented are from the largest amount of computer vision technologies in the ethical issue to the least amount.

6.2.1 Espionage

Based on the literature review, espionage is found to be the most concerning problem in the field of computer vision, as it concerns the largest amount of different computer vision applications. Based on the findings from sampled literature, categories that align with the ethical issue of espionage are image classification, face recognition, character recognition, image database, action and motion recognition and computational camera (Table 3).

TABLE 3 Computer Vision technologies related to Espionage

Ethical issue	**Computer Vision Application**
ESPIONAGE	**Image classification** (Spyromitros-Xioufis et al. 2016) **Face Recognition** (Tian et al., 2011), (Grandjean et al., 2008) **Character Recognition** (Senior & Pankati, 2011) **Image Database** (Puglisi et al., 2015), (Senior & Pankati, 2011) **Action and Motion Recognition** (Padilla-López, Chaaraoui & Flórez-Revuelta, 2015) **Comp. camera** (Senior & Pankati, 2011)

In this definition, espionage is classified as an act of spying or collecting data on individuals without their consent. Espionage can be done by both individuals and organisations, and from the ethical point of view, is a serious breach of individual's privacy. (Baase, 2003.)

According to Spyromitros-Xioufis et al. (2016) study, automatic image classification can cause privacy problems, when images are shared over social networks as a daily practice. The information within image not only contains user's social ties, but also their relation to other users and various third parties. The discrepancy is caused by the fact that the users are often not able to fully determine what they want to share and what they end up sharing on the Internet, as some of the classification data and metadata of the images is automatically generated by computer vision. It's often not clear what the user is disclosing and what information gets leaked with the process of sharing images to the internet, enabling undesired individuals or parties to spy on the person.

Additionally, according to Puglisi et al. (2015), image classification can be assisted by user adding their tags to images in various systems, like online social services. Users are able to freely choose tags and combine terms however they want. This can lead to users revealing their preferences, activities and interests, and pose a potential privacy risk. They are exposed to possible privacy breaches and various spying activities, both my legitimate and less legitimate parties and entities.

Spying is often heavily associated with surveillance. According to Tian et al. (2014), the primary concerns of social acceptance regarding the surveillance technologies that utilize context aware computer vision applications are that of privacy and security. Due to the nature of surveillance itself, the systems jeopardize the privacy and security of people inherently. The passive monitoring of people is done in the name of security, but at the same time the identities of passively monitored people can be easily captured with the presence of computer vision technologies, namely face recognition.

According to Grandjean et al. (2008), the continuous rapid development of face recognition techniques potentially empowers those who wish to exploit that technology unethically. The psychological theorizing of enabling face recognition techniques to utilize emotion reading further complicate the matter of breaching the individual's privacy. With face recognition tools being able to detect emotions of subjects on a video or an image, the exploiters might utilize this to read the minds of subjects. Grandjean et al. (2008) also note that this is enabled by face recognition tools reading the micro expressions across the faces of individual people, and giving them direct access to thoughts of people, which further embodies the invasive nature of recognition techniques.

Since from the ethical standpoint it's important to preserve the privacy of individual by protecting their identity or sensitive information, there has to be a way for the system to identify information to preserve privacy. Padilla-López er al. (2015) note that since video surveillance tools assisted by computer vision are becoming more often operated in private spaces, intelligent systems such as

these should be designed and developed so that they take privacy of individuals into account by the means of new tools that can restore the right to privacy of an individual.

Regarding databases, Senior & Pankati (2011) claim that the public becomes more uneasy as databases of tagged images become more accessible and vulnerable to the process of "function creep", which means that they are used for the spying purposes that are not intended. This becomes more profound as several of these databases are linked between, so the searches become possible across several domains. Such databases are more than often used to assist various computer vision applications.

According to Padilla-López, Chaaraoui & Flórez-Revuelta (2015), the recent advances in computer vision have enabled the development of intelligent surveillance in so called "ambient-assisted living" in part of system of smart houses. By using computer vision technologies combined with visual capabilities, the house systems can automatically interpret data in the environment, such as actions made by individuals, and perform various automated assisted tasks. The achievements made in developing smart house systems utilizing computer vision applications represents a vast improvement concerning the technology itself, but also poses a great threat to the privacy of their users. As the capabilities presented to such systems enhanced with computer vision technology like action and motion recognition give them ability to gather and index huge amounts of data about each individual, it is ethically questionable what kind of actions and motions should be allowed to be viewed. (Padilla-López, Chaaraoui & Flórez-Revuelta, 2015.)

Senior and Pankati (2011) note that while the purpose of computational camera technologies used in surveillance is to aid a detection of a single piece of information, such as the number of people in the queue, the exact same application can be equally used to surveil people. The ethical problem lies in the fact that it's impossible for the subjects who are under observation by such computer vision utilizing technologies to know how the data gained from them is handled, and these devices will always pose a potential and publically perceived privacy threat.

6.2.2 Identity theft

Identity theft proved to be the second most concerning problem in the field of computer vision. Similar in intention to espionage, identity theft is a form of act of crime, punishable by law. It is also recognized to be a serious ethical issue in information systems (Baase, 2003). Based on the findings of sampled literature, categories that align with the ethical issue of identity theft are image classification, face recognition, character recognition and content-based image retrieval (Table 4).

TABLE 4 Computer Vision technologies related to Identity Theft

Ethical issue	**Computer Vision Technology(s)**
IDENTITY THEFT	**Image classification** (Lorenzi & Vaidya, 2011) **Face recognition** (Tian et al., 2011) **Character Recognition** (Dey et al., 2014) **Content-Based Image Retrieval** (Zhuo et al., 2013)

Identity theft is a process of stealing another individual's identity for various malicious purposes, such as obtaining various benefits in the name of another person. The personal data that is targeted by theft can be credit cards, passports and driver's licenses. (Baase, 2003.)

Image classification in computer vision can classify accurately images that might contain such sensitive data. According to Lorenzi & Vaidya (2011), a potential to breach to steal such information exist through the use of image classification. The modern tools of image classification can automatically classify images to filter out desired sensitive data from the masses of other data. Such data becomes available to attackers when sensitive personal data is disclosed through email, for example. In the case that the attacker gets access to the individual's computer, they are able to scan the hard drive for sensitive images or other media. Since image classification can accurately pinpoint where the sensitive information is within possible vast collection of images or other media on hard drive, the extraction of sensitive data becomes effortless and fast. Being able to accurately classify and extract this kind of sensitive information from images easily enables attackers to conduct fraud like identity theft (Lorenzi & Vaidya, 2011).

According to Tian et al. (2014), as the technologies that utilize face recognition techniques often store sensitive personal information. This make the applications of face recognition prone to the security breaches, making the personal data exposed to personnel who would use it for the purposes of identity theft.

Additionally, with computer vision recognition techniques, a photo can be potentially mined to reveal a vast personal information about an individual other than information about faces and facial features, such as height, weight, ethnicity and gender. Thus, a photo collection with different amounts of data about an individual can be mined with various computer vision recognition techniques to reveal a more vivid picture about an individual to easily obtain his or her identity. (Dey et al., 2014.)

According to Dey et al. (2014), in addition to such individual features as weight or height, with character recognition techniques, information of a photo collection can be obtained to mine a whole story about an individual or a community of people in the photos.

The number of digital images available over the Internet rapidly grows, as multimedia and Internet technologies develop alongside with computer vision and the research on the "personalized" content-based image retrieval becomes a topical research topic (Zhuo et al., 2013). In this context, Zhuo et al. (2014) express that "personalized" means that the retrieval techniques collect user's personal information for the sake of providing more accurate results for various users of retrieval technologies. However, due to inclusion of personal information, the approach of personalized content-based research becomes more sensitive to the breaches of privacy. Such personal information is thus easy to misuse for different malicious purposes, like identity theft, or sold to different parties illegally.

6.2.3 Malicious attacks

Malicious attacks is the third most prominent of ethical issues in computer vision and has a several numbers of research papers supporting some of the areas. Based on the findings from sampled literature, categories that align with ethical issue of malicious attacks are computational camera, face recognition and reverse image search (Table 5).

TABLE 5 Computer Vision technologies related to Malicious Attacks

Ethical issue	**Computer Vision Technology**
MALICIOUS AT-TACKS	**Compuntational camera** (Winkler & Rinner, 2010), (Winkler & Rinner 2014)
	Face recognition (Jain & Kumar, 2012)
	Reverse image search (Lorenzi et al., 2015), (Mehrnezhad et al., 2015.)

Malicious attacks refer to the intentions of criminals to hack or break into the systems for various purposes, or to spread malicious data to recipients. Hackers or cyber criminals break into the systems they should not have access to (Baase, 2003).

Some of computational smart camera applications are often used in video surveillance. A number of issues exists with the introduction of such computer vision application to the surveillance. Most of these issues concern the privacy of the people monitored, but also the security of video surveillance systems against the targeted attacks and abuse. In comparison to classical analog video surveillance, digital video can be easily stored and indexed, and computer vision technology opens possibilities to derive behaviour patterns not only from suspected people targeted for surveillance, but also from innocent people. (Winkler & Rinner, 2010.)

Rinner & Winkler (2014) claim that confidentiality of the data must be ensured throughout the entire lifetime of an image. That includes the image capturing in smart cameras, and continuing to the long-term archiving of an image to the database, where it's classified. The definition of the sensitive data is not only limited to the information obtained from raw images, but also data from processed images and all types of derived information from them. This is to ensure that the data security properties are tightly bound to the sensitive data, and have the same lifetime to avoid potential security breaches.

Ethically, only in cases where for example law is violated and a person becomes suspected should the personal information of interest be collected to authorized parties. However, according to Winkler & Rinner (2010), the capability of a surveillance system to detect privacy sensitive regions, such as faces by computer vision recognition techniques, effectively put any individual's privacy at risk, even if the person in question is innocent. If any component of the system does not work reliably, the privacy is at risk and prone to malicious attacks by hackers.

Additionally, according to Jain & Kumar (2012), biometric systems, including face recognition techniques and information obtained from them, are vulnerable to potential breaches of security from malicious attacks. Various security vulnerability result from various errors like intrinsic failures and adversary attacks. The major security concern deals with biometric templates as the storage of sensitive information, like recognised faces, might be vulnerable to attacks, and even the highest levels of security can be potentially compromised.

Such attacks can happen in various ways. For example, a Trojan horse attack works by replacing the recognition system's feature extractor with a program that generates the feature set desired for theft. Another form of malicious intent comes in a form of spoofing, where the feature vectors that were generated with face recognition systems are replaced by fake synthetically generated features. (Jain & Kumar, 2012.)

Additionally, according to Lorenzi et al. (2015), computer vision tools, namely reverse image search, can be used to perform malicious attacks against CAPTCHA images that are used to identify the authenticity of a user by testing whether the access is being requested by a real user or automated bot by the means of Turing Test. The results of CAPTCHA breaches tested by Lorenzi et al. (2015) indicate that Reverse Image Search engines can identify exact match for an image and the metadata associated with it to effectively compromise the in-

tegrity of the CAPTCHA identification method. As computer vision automation and image processing becomes increasingly powerful online, the development of new methods to secure online assets from automated bots are required (Lorenzi et al., 2015).

More support was given that reverse image search being used maliciously against CAPTCHA verifications. Since free web services are becoming increasingly available through the Internet, it attracts a lot of attention to them misuse through automated bots. This makes it important for the service providers to distinguish whether the user is human or a machine. However, Mehrnezhad et al. (2015) note in their experiments that visual changes made to the publicly available images used by CAPTCHA engines are still recognizable by modern computer vision technologies despite various changes. Reverse search engines were able to identify changes, such as resize, cutting, rotation, slight colour and light alterations and texture changes and match the manipulated image to its original source and metadata, making image based CAPTCHAS susceptible to automated bot attacks.

6.2.4 Copyright infringement

Copyright infringement was found to be an ethical issue of some computer vision technologies. Based on the findings from sampled literature, categories that align with the ethical issue of copyright infringement are image database and content-based image retrieval (Table 6).

TABLE 6 Computer Vision technologies related to Copyright Infringement

Ethical issue	**Computer Vision Technology**
COPYRIGHT INFRINGEMENT	**Image database** (Gloe & Böhme, 2010)
	Content-Based Image Retrieval (Müller et al., 2004)

Copyright infringement is defined to be an illegal use of intellectual property without rights or permission. Copyrighted material also include trademarks, patents and other copyrighted material (Baase, 2003).

The databases used for computer vision tools are proving useful to researchers and also forensic investigators. Digital photos found in the databases often depict authentically various realistic scenes. However, the problem in these databases lies in avoiding pictures with scenes that might be susceptible to either copyright violations, or privacy related issues. (Gloe & Böhme, 2010.)

Additionally, according to Müller et al. (2004), content based image retrieval is becoming an increasingly important subject in medical image research and with image management related systems. Several of these retrieval technologies and methodologies are used in a variety of applications, such as medical image classification and diagnostic aid and automatic labelling of images. Several of large medical image databases are becoming available publicly for the sake of improving the performance of such systems, but the databases are vulnerable to breach of patient privacy and may contain copyrighted or private images. Müller et al. (2004) note that despite efforts made to anonymise the images in databases and to minimize the risk of containment of copyrighted or sensitive data, it is clear that such systems are still prone misuse of intellectual property.

6.2.5 Discrimination

Discrimination was found to align with recognition techniques. For the ethical issue of *discrimination*, two of the computer vision categories were recognized (Table 7) based from the finding of sampled literature, which are face recognition and action and motion recognition.

TABLE 7 Computer Vision technologies related to Discrimination

Ethical issue	**Computer Vision Technology**
DISCRIMINATION	**Face recognition** (Tian et al., 2011) **Action and Motion recognition** (Coudert, 2010).

A threat identified with face detection techniques according to Tian et al. (2014) has to do with human skin detection. The computer vision applications that can differentiate between the skin coloration and facial features related to ethnicity and can be used to discriminate certain groups of people by thought of criminal tendency. These groups of people, based on their skin colour, can be discriminated against whether they actually are proven guilty or innocent.

Additionally, according to Coudert (2010), computer vision technologies are implemented into video surveillance to improve the efficiency of surveillance systems. It serves various purposes, such as identification and tracking of objects like suspects and cars, and to identify suspicious behaviours or emergency situations. Essentially, computer vision technologies provide the necessary need to operate through the high capacity of various data and automate various tasks of detection. Coudert (2010) notes however, that the increased use

of computer vision technologies in surveillance systems has rendered individuals exposed to automatic decisions. It enforces the tracking of behaviour patterns, which can result in consequences that are harmful for individuals and lead to discriminatory practices. This mean that innocent people may experience discrimination and labelled suspects automatically based on their behaviour. Coudert (2010) claims that such profiling technologies enforced by computer vision applications may pose risk to phenomenon called "de-individualisation", where people of a certain groups are judged and treated by the group characteristics, which are not always valid to determine whether they are innocent or not, and is a matter of serious ethical concerns.

6.2.6 Misinformation

Misinformation was found to align with one category of computer vision, computational cameras (Table 8). Despite being only one ethical issue in one computer vision category, it is still notable and deserves attention. In its basis, misinformation refers to the act of regulating communication media in a way that it's deceptive to individuals to gain something (Baase, 2003).

TABLE 8 Computer Vision technologies related to Misinformation

Ethical issue	**Computer Vision Technology**
MISINFORMATION	**Compuntational Camera** (Quinn, 2003),

Computer vision enables the cameras to 'smart' shoot photographs. The manipulations that the computational camera does occur during the actual shoot, and these manipulations include various settings, for example how camera frames the image or measures things like light or exposure of a photo taken at that moment (Quinn, 2003).

In the lights of ethics, the use of smart cameras affects whether the moral reasoning of a photojournalist, using a smart camera that alters settings during the shoot of its own, is good or bad professional practise. In examining this issue, according to Quinn (2003), one must refer to the professional ethic codes of photojournalism. The author notes however, that the ethics codes of photojournalism are in some cases poorly informed and conveyed in such ways that is not clearly understandable or applicable in every situation.

At the basis of these codes, a photojournalist who does not abide the common moral reasoning and codes of ethics of journalism, conveys the visual news with bias and prejudice to the recipients of said news. This process ren-

ders the information passed to the public tainted and ambiguous, and in the worst cases misleading or useless. (Quinn, 2003).

6.3 Discussion

The research problem of this paper was to find ethical issues that concern the area of computer vision. Based on the integrative literature review and the synthesis of different types of literatures on the topic of various ethical issues concerning different application of computer vision, several ethical issues were found. The ethical issues are as follows, from the most common to least common:

1. Espionage
2. Identity theft
3. Malicious attacks
4. Copyright infringement
5. Discrimination
6. Misinformation

Based on the findings, some of the computer vision areas had less ethical issues than others. The synthesis of review literature revealed that the most ethically concerning computer vision application is *face recognition,* having four different ethical issues. This could be due to the fact that we as humans feel that our faces have the most potential risk regarding privacy. This could indicate that a lot of research goes into recognizing ethical issues of face recognition because of this fact. It is also important to notice that out of all research that goes into the research area of computer vision, most of it goes into technologies that utilize face recognition. This was first noted in the theoretical section of this study. Additionally, this this could also indicate that computer vision areas that are less obvious regarding privacy and security get less attention from researchers, but could possibly have ethical issues if more research would be allocated into them.

It is also worth noting that most of the papers that were found during the keyword search proved to be recently written. Most of the papers date after year 2010, with a substantial amount being written between years 2015 and 2017. Only a few papers dated before year 2010. This could mean that the research area is still fresh and new, and that the new ethical issues that relate to trending computer vision applications are being researched continuously and more and more as time progresses.

6.3.1 Areas with the lack of research

Out of all trending computer vision applications, only several did not have any literature to connect it to any of the ethical issues. There were no research papers on the issues of location recognition, despite the technology having possibilities like telling the location of taken image. This could be due to the fact that objects that are recognized with this technology to determine location do not have any obvious private properties themselves, unlike the human face and features in face recognition.

The other area with a lack of ethical research proved to be cognitive services available on the Internet. Since they started making appearance only in recent years, it is entirely possible that no research have yet done regarding them. However, this does not mean that they automatically lack ethical issues, and this should be considered for the future research.

Out of computer ethics related keyword that were used in the search, accessibility didn't yield any results. This could be seen as either due to the fact that accessibility does not have many implication that align with the area of computer vision, or simply indicate that there are currently no research that would link any ethical issues related to accessibility to any computer vision technologies.

6.3.2 Evaluation of this paper

A lot of emphasis was put so that this study would yield valid and reliable resources to answer the research question. The integrative literature review method proved to be a good choice for this type of research, as the final sample of reviewed literature consisted evenly on both theoretical and empirical papers. The final sample of 18 research papers were all from prestige journals and conference proceedings, and had passed the screening process which determined whether the research methodology was reliable.

This study was put under some restrictions to make the scope of the study realistic to the allocated resources and time given to complete it. First of all, no studies were taken into account that dated before year 2000. This is due to the fact that the research area of this paper is computer vision technologies that are considered new and trending. Secondly, other cognitive vision systems and areas, like artificial intelligence and machine vision were left out. Those areas of research would need to be identified separately so that proper research could be put into them, considering the resource and time limitations of master's thesis. The scope of this study was thus well defined and allowed to allocate given resources properly to finish this study.

The most time consuming part of this study was the integrative literature review itself. Since it is done in a systematic way to provide most reliable results, a lot of time was used to screen the articles so that the final sample consisted of reliable and valid data. To ensure transparency, the instrument of col-

lection was included in this study, which can be viewed in the appendix of this paper.

Overall, the author of this study finds it successful in both own learning, and providing new kind of information to the topic area of research. The study successfully fulfils its purpose in both providing an answer to the research question and filling the knowledge gap in the area of computer vision.

7 Conclusion

New emerging computer vision technologies are becoming common with many software frameworks available for use. The research area of computer vision has hence become very topical, consisting of many other sub-domains of applications and technologies. These topical areas are, for example, face recognition, image content retrieval or computational photography. The basic idea of the computer vision technologies is to automate and replicate the human vision system. This requires a high level of image analyzing, processing and learning. With any kind of rapidly emerging technology, questions of their ethical implications arise. The field of ethics is designed to examine the issues of such implications. The field of computer ethics specifically examines the issues of information technology, which computer vision is part of.

The purpose of this study was to find ethical issues that concern recent topical computer vision applications. Based on the results, ethical issues that were identified to concern recent computer vision applications are espionage, identity theft, malicious attacks, copyright infringement, discrimination and misinformation. The results were synthesized from reviewed literature, which was collected systematically with the method of integrative literature review.

Based on this study, computer vision shares a substantial collection of different ethical issues. Recent progress in the research area of computer vision poses many dilemmas and concerns that should be taken into account to ensure both privacy and security of individuals, and other codes of conducts related to good ethical practices both in computer ethics and professional ethics.

Much of the research done in the area of computer vision and ethics is new and it seems like more research is currently emerging fast on this subject. However, some of the areas in computer vision lack ethical research altogether, like location recognition or emerging cognitive Internet services.

Findings of this study can potentially guide other researches to areas of computer vision that have need of more research on ethics. This makes the study valuable and brings new knowledge to the research area that didn't exist before. Further research can be done to include other fields of vision, like machine vision, robotics vision or artificial intelligence. The definition of ethics

could be also expanded in the future studies to include more perceived ethical issues, and new emerging studies. In the future, the research could be also expanded to include solutions to the exact ethical issues that were identified in this study.

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APPENDIX 1 INSTRUMENT OF LITERATURE REVIEW

(First) Author	Publication date	Title of article or chapter	Book/Journal/Conference title	Database used	Keyword search	Research Design
Quinn	Jul-03	Accepting manipulation or manipulating what's acceptable?	Australian Computer Society	ACM	ethic + computer vision	theoretical
Lorenzi	Feb-11	Identifying a critical threat to privacy through automatic image classification	In Proceedings of the first ACM conference on Data and application security and privacy	ACM	privacy + computer vision	experimental
Winkler	Aug-10	A systematic approach towards user-centric privacy and security for smart camera networks.	In Proceedings of the Fourth ACM/IEEE International Conference on Distributed Smart Cameras	ACM	privacy + computer vision	theoretical
Rinner	Nov-14	Privacy-protecting smart cameras.	In Proceedings of the ACM International Conference on Distributed Smart Cameras	ACM	privacy + computer vision	theoretical

Tian	Jan-14	Threat-based evaluation for context-aware multimedia surveillance system.	In Proceedings of the 8th International Conference on Ubiquitous Information Management and Communication	ACM	privacy + computer vision	experimental
Dey	Oct-14	Estimating heights from photo collections: A data-driven approach.	In Proceedings of the second ACM conference on Online social networks	ACM	privacy + computer vision	Quantitative
Lorenzi	Jun-15	Generating secure images for CAPTCHAs through noise addition.	In Proceedings of the 20th ACM Symposium on Access Control Models and Technologies	ACM	security + reverse image search	experimental
Gloe	Mar-10	The dresden image database for benchmarking digital image forensics	Journal of Digital Forensic Practice	ACM	copyright + image database	experimental
Zhuo	Aug-13	Hierarchical privacy preservation for personalized image retrieval.	In Proceedings of the Fifth International Conference on Internet Multimedia Computing and Service	ACM	privacy + image retrieval	experimental

Eleftherios Spyromitros-Xioufis	Jun-16	Personalized privacy-aware image classification.	In Proceedings of the 2016 ACM on International Conference on Multimedia Retrieval	ACM	security + image classification	theoretical
Padilla-López	Jun-15	Visual privacy protection methods: A survey.	Expert Systems with Applications	EBSCO	security + computer vision	qualitative
Coudert	Jul-10	Privacy implications of pattern recognition technologies	Computer Law & Security Review	EBSCO	privacy + computer vision	theoretical
Mehrnezhad	Apr-17	PiSHi: click the images and I tell if you are a human.	International Journal of Information Security	EBSCO	security + reverse image search	experimental
Müller	Sep-04	A reference data set for the evaluation of medical image retrieval systems.	Computerized Medical Imaging and Graphics,	EBSCO	privacy + image database	experimental
Puglisi	Sep-15	On content-based recommendation and user privacy in social-tagging systems.	Computer Standards & Interfaces	EBSCO	privacy + Query by image content	theoretical

Grand-jean	Dec-08	Sociological and Ethical Issues in Facial Recognition Systems: Exploring the Possibilities for Improved Critical Assessments of Technologies?	Multimedia, 2008. ISM 2008. Tenth IEEE International Symposium	IEEE	ethic + face recognition	theoretical
Senior	2011	Privacy protection and face recognition.	In Handbook of Face Recognition	Springer	privacy + face recognition	theoretical
Jain	Jul-05	Biometric recognition: an overview.	In Second Generation Biometrics: The Ethical, Legal and Social Context	Springer	ethic + recognition	theoretical